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PART 1

Pinging 3 times from h2 to h5, we observe the following latencies when using a learning switch.

mininet> h2 ping -c 3 h5

PING 10.0.0.5 (10.0.0.5) 56(84) bytes of data.

64 bytes from 10.0.0.5: icmp_seq=1 ttl=64 time=7.71 ms

64 bytes from 10.0.0.5: icmp_seq=2 ttl=64 time=0.172 ms

64 bytes from 10.0.0.5: icmp_seq=3 ttl=64 time=0.044 ms

--- 10.0.0.5 ping statistics ---

3 packets transmitted, 3 received, 0% packet loss, time 2012ms

rtt min/avg/max/mdev = 0.044/2.641/7.708/3.583 ms

Pinging 3 times from h2 to h5, we observe the following latencies when using a controller hub.

mininet> h2 ping -c 3 h5

PING 10.0.0.5 (10.0.0.5) 56(84) bytes of data.

64 bytes from 10.0.0.5: icmp_seq=1 ttl=64 time=7.29 ms

64 bytes from 10.0.0.5: icmp_seq=2 ttl=64 time=4.19 ms

64 bytes from 10.0.0.5: icmp_seq=3 ttl=64 time=4.02 ms

--- 10.0.0.5 ping statistics ---

3 packets transmitted, 3 received, 0% packet loss, time 2003ms

rtt min/avg/max/mdev = 4.018/5.165/7.285/1.500 ms

We can clearly observe that the round trip time of the ping packets decrease after the first ping in case of the learning switch whereas in the case of the controller hub, the round trip time of the ping packets is always high. This is because the hub always floods the incoming packets onto all outgoing

ports except the port from which it got the packet. This increases traffic on the network thus, causing higher delays. On the other hand, a learning switch only floods the packet when it encounters it for the very first time. This is why the round trip time is high for the first ping packet. For the second and third ping packet, since the switch learns the routes, the delay is quite less comparatively and it also doesn't require any flooding.

After running pingall for learning switch, the following rules are installed on the switch.

mininet> dpctl dump-flows

*** s1 ----------

cookie=0x0, duration=184.182s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=184.180s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=184.175s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=184.174s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=184.168s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=184.166s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04 actions=output:"s1-eth4"

cookie=0x0, duration=184.159s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=184.158s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s1-eth4"

cookie=0x0, duration=184.149s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=184.148s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=184.142s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=184.141s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:04 actions=output:"s1-eth4"

cookie=0x0, duration=184.134s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=184.133s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:05 actions=output:"s1-eth4"

cookie=0x0, duration=184.122s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=184.121s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:04 actions=output:"s1-eth4"

cookie=0x0, duration=184.114s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=184.113s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:05 actions=output:"s1-eth4"

cookie=0x0, duration=186.472s, table=0, n_packets=28, n_bytes=1680, priority=0 actions=CONTROLLER:65535

*** s2 ----------

cookie=0x0, duration=184.173s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth3"

cookie=0x0, duration=184.169s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=184.164s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth3"

cookie=0x0, duration=184.161s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth2"

cookie=0x0, duration=184.147s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"

cookie=0x0, duration=184.144s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=184.139s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"

cookie=0x0, duration=184.136s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth2"

cookie=0x0, duration=184.127s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth3"

cookie=0x0, duration=184.124s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=184.119s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth3"

cookie=0x0, duration=184.116s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth2"

cookie=0x0, duration=184.105s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=184.104s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth2"

cookie=0x0, duration=186.476s, table=0, n_packets=24, n_bytes=1400, priority=0 actions=CONTROLLER:65535

After running pingall for the controller hub, we have the following rules.

mininet> dpctl dump-flows

*** s1 --

cookie=0x0, duration=12.228s, table=0, n_packets=80, n_bytes=5600, priority=0 actions=CONTROLLER:65535

*** s2 --

cookie=0x0, duration=12.230s, table=0, n_packets=80, n_bytes=5600, priority=0 actions=CONTROLLER:65535

PART 2

Results on running pingall:

loading app firewall_monitor.py

loading app ryu.controller.ofp_handler

instantiating app firewall_monitor.py of FirewallApp

instantiating app ryu.controller.ofp_handler of OFPHandler

packet in 1 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 1

packet in 1 00:00:00:00:00:02 00:00:00:00:00:01 2

packet in 2 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 3

packet in 1 00:00:00:00:00:01 00:00:00:00:00:02 1

packet in 1 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 1

packet in 1 00:00:00:00:00:03 00:00:00:00:00:01 3

Packet count for h3 on switch s1: 1

packet in 2 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 3

packet in 1 00:00:00:00:00:01 00:00:00:00:00:03 1

packet in 1 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 1

packet in 2 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 3

packet in 2 00:00:00:00:00:04 00:00:00:00:00:01 1

packet in 1 00:00:00:00:00:04 00:00:00:00:00:01 4

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 1

packet in 2 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 3

packet in 2 00:00:00:00:00:05 00:00:00:00:00:01 2

packet in 1 00:00:00:00:00:05 00:00:00:00:00:01 4

packet in 1 00:00:00:00:00:01 00:00:00:00:00:05 1

packet in 2 00:00:00:00:00:01 00:00:00:00:00:05 3

packet in 1 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 2

packet in 1 00:00:00:00:00:03 00:00:00:00:00:02 3

Packet count for h3 on switch s1: 2

packet in 2 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 3

packet in 1 00:00:00:00:00:02 00:00:00:00:00:03 2

packet in 1 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 2

packet in 2 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 3

packet in 2 00:00:00:00:00:04 00:00:00:00:00:02 1

packet in 1 00:00:00:00:00:04 00:00:00:00:00:02 4

packet in 1 00:00:00:00:00:02 00:00:00:00:00:04 2

packet in 2 00:00:00:00:00:02 00:00:00:00:00:04 3

packet in 1 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 2

packet in 2 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 3

packet in 2 00:00:00:00:00:05 00:00:00:00:00:02 2

packet in 1 00:00:00:00:00:05 00:00:00:00:00:02 4

packet in 1 00:00:00:00:00:02 00:00:00:00:00:05 2

packet in 1 00:00:00:00:00:03 ff:ff:ff:ff:ff:ff 3

Packet count for h3 on switch s1: 3

packet in 2 00:00:00:00:00:03 ff:ff:ff:ff:ff:ff 3

packet in 2 00:00:00:00:00:04 00:00:00:00:00:03 1

packet in 1 00:00:00:00:00:04 00:00:00:00:00:03 4

packet in 1 00:00:00:00:00:03 00:00:00:00:00:04 3

Packet count for h3 on switch s1: 4

packet in 2 00:00:00:00:00:03 00:00:00:00:00:04 3

packet in 1 00:00:00:00:00:03 ff:ff:ff:ff:ff:ff 3

Packet count for h3 on switch s1: 5

packet in 2 00:00:00:00:00:03 ff:ff:ff:ff:ff:ff 3

packet in 2 00:00:00:00:00:05 00:00:00:00:00:03 2

packet in 1 00:00:00:00:00:05 00:00:00:00:00:03 4

packet in 1 00:00:00:00:00:03 00:00:00:00:00:05 3

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 1 00:00:00:00:00:01 00:00:00:00:00:04 1

packet in 2 00:00:00:00:00:04 ff:ff:ff:ff:ff:ff 1

packet in 2 00:00:00:00:00:05 00:00:00:00:00:04 2

packet in 1 00:00:00:00:00:04 ff:ff:ff:ff:ff:ff 4

packet in 2 00:00:00:00:00:04 00:00:00:00:00:05 1

packet in 1 00:00:00:00:00:02 00:00:00:00:00:05 2

packet in 1 00:00:00:00:00:02 00:00:00:00:00:05 2

packet in 1 00:00:00:00:00:02 00:00:00:00:00:05 2

packet in 1 00:00:00:00:00:02 00:00:00:00:00:05 2

packet in 1 00:00:00:00:00:03 00:00:00:00:00:05 3

packet in 1 00:00:00:00:00:03 00:00:00:00:00:05 3

packet in 1 00:00:00:00:00:03 00:00:00:00:00:05 3

packet in 1 00:00:00:00:00:03 00:00:00:00:00:05 3

mininet> pingall

*** Ping: testing ping reachability

h1 -> h2 h3 X h5

h2 -> h1 h3 h4 X

h3 -> h1 h2 h4 X

h4 -> X h2 h3 h5

h5 -> h1 X X h4

*** Results: 30% dropped (14/20 received)

We can see that due to the firewall, the ping packet between h1 and h4, h2 and h5, h3 and h5 are blocked. That’s why we get an X in the output above.

Rules installed on both switches:

mininet> dpctl dump-flows

*** s1 ----------

cookie=0x0, duration=573.296s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=573.294s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=573.288s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=573.287s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=573.281s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=563.274s, table=0, n_packets=5, n_bytes=322, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"

cookie=0x0, duration=563.273s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s1-eth4"

cookie=0x0, duration=563.264s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=563.263s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=563.257s, table=0, n_packets=4, n_bytes=280, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=563.256s, table=0, n_packets=3, n_bytes=182, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:04 actions=output:"s1-eth4"

cookie=0x0, duration=563.249s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"

cookie=0x0, duration=553.237s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=553.233s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:04 actions=output:"s1-eth4"

cookie=0x0, duration=553.221s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s1-eth4",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"

cookie=0x0, duration=644.328s, table=0, n_packets=43, n_bytes=2478, priority=0 actions=CONTROLLER:65535

*** s2 ----------

cookie=0x0, duration=573.285s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth3"

cookie=0x0, duration=563.281s, table=0, n_packets=5, n_bytes=322, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth3"

cookie=0x0, duration=563.275s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth2"

cookie=0x0, duration=563.262s, table=0, n_packets=4, n_bytes=280, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"

cookie=0x0, duration=563.259s, table=0, n_packets=3, n_bytes=182, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=563.254s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"

cookie=0x0, duration=553.246s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth3"

cookie=0x0, duration=553.236s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s2-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=553.229s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth3"

cookie=0x0, duration=533.218s, table=0, n_packets=4, n_bytes=280, priority=1,in_port="s2-eth2",dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth1"

cookie=0x0, duration=533.214s, table=0, n_packets=3, n_bytes=182, priority=1,in_port="s2-eth1",dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth2"

cookie=0x0, duration=644.331s, table=0, n_packets=21, n_bytes=1106, priority=0 actions=CONTROLLER:65535

To minimize the number of firewall rules on the switch,

- Instead of creating separate rules for each host-to-host block, we can create wildcard rules that apply to a range of hosts.
- Consolidate Rules for Symmetrical Blocks: If we have symmetrical blocking requirements (e.g., H2-H3 with H5 and H1 with H4), we can consolidate the rules by handling the communication in one direction and using the same rule for the reverse direction

To ensure that pre-existing rules do not interfere with real-time firewall policy updates, the network operator can follow these best practices:

1. Rule Priority: Assign different priorities to pre-existing rules and real-time firewall rules. Real-time rules should have higher priorities to take precedence over existing rules.

2. Rule Conflict Resolution: Implement a conflict resolution mechanism to handle situations where real-time rules conflict with pre-existing rules. When a conflict occurs, the controller can choose to either allow the real-time rule to override the pre-existing rule

PART 3

After implementing load balancing on the switch, we get the following output for various pings.

mininet> h1 ping -c 1 10.0.0.42

PING 10.0.0.42 (10.0.0.42) 56(84) bytes of data.

--- 10.0.0.42 ping statistics ---

1 packets transmitted, 1 received, 0% packet loss, time 0ms

The selected server is ===> 10.0.0.4

<========Packet from client: 10.0.0.1. Sent to server: 10.0.0.4, MAC: 00:00:00:00:00:04 and on switch port: 1========>

<++++++++Reply sent from server: 10.0.0.4, MAC: 00:00:00:00:00:04. Via load balancer: 10.0.0.42. To client: 10.0.0.1++++++++>

mininet> h2 ping -c 1 10.0.0.42

PING 10.0.0.42 (10.0.0.42) 56(84) bytes of data.

--- 10.0.0.42 ping statistics ---

1 packets transmitted, 1 received, 0% packet loss, time 0ms

The selected server is ===> 10.0.0.5

<========Packet from client: 10.0.0.2. Sent to server: 10.0.0.5, MAC: 00:00:00:00:00:05 and on switch port: 2========>

<++++++++Reply sent from server: 10.0.0.5, MAC: 00:00:00:00:00:05. Via load balancer: 10.0.0.42. To client: 10.0.0.2++++++++>

mininet> h3 ping -c 1 10.0.0.42

PING 10.0.0.42 (10.0.0.42) 56(84) bytes of data.

--- 10.0.0.42 ping statistics ---

1 packets transmitted, 1 received, 0% packet loss, time 0ms

The selected server is ===> 10.0.0.4

<========Packet from client: 10.0.0.3. Sent to server: 10.0.0.4, MAC: 00:00:00:00:00:04 and on switch port: 1========>

<++++++++Reply sent from server: 10.0.0.4, MAC: 00:00:00:00:00:04. Via load balancer: 10.0.0.42. To client: 10.0.0.3++++++++>

We can observe above that the load balancer causes the request to alternate between the server at h4 and h5 with every ping that is sent.

If we were to implement a load balancing policy that considers the load on these servers, we can use the weighted round-robin policy. It assigns weights to each server (H4 and H5) based on their processing capacity or current load, modifies the load balancer to distribute requests to servers in a round-robin fashion according to their weights and servers with higher weights will receive more requests, while servers with lower weights will receive fewer requests.